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(54) Bioelectrical impedance measuring method and body composition measuring apparatus

Verfahren zur Messung der bioelektrischen Impedanz und Vorrichtung zur Bestimmung der Körperzusammensetzung

Procédé pour mesurer l'impédance bioélectrique et dispositif de mesure de la composition d'un corps

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(56) References cited:
WO-A-96/08198

- **NAWARYCZ T ET AL.: "Triple-Frequency Electroimpedance Method for Evaluation of Body Water Compartments" MEDICAL & BIOLOGICAL ENGINEERING & COMPUTING, vol. 34, suppl. 1, part 2, 1996, pages 181-182, XP000965197**
- **THOMAS B J ET AL: "Bioimpedance Spectrometry in the Determination of Body Water Compartments: Accuracy and Clinical Significance" APPLIED RADIATION AND ISOTOPES,GB,PERGAMON PRESS LTD., EXETER, vol. 49, no. 5-6, 6 May 1998 (1998-05-06), pages 447-455, XP004110545 ISSN: 0969-8043**
- **ZHAO T-X ET AL: "Triple-frequency method for measuring blood impedance" PHYSIOLOGICAL MEASUREMENT, vol. 14, 1993, pages 145-156, XP002152895 UK**

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Description

TITLE OF THE INVENTION

[0001] Bioelectrical Impedance Measuring Method and Body Composition Measuring Apparatus

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a bioelectrical impedance measuring method and a body composition measuring apparatus.

Description of the Prior Art

[0003] An electrical impedance of a living body is typically represented by a lumped constant equivalent circuit comprising an extra-cellular fluid resistance Re, an intra-cellular fluid resistance R_i, and a cell membrane capacitance Cm, as shown in Fig. 1. Practically, plural cells making up the living body are respectively represented by individual circuits having different constants due to their different shapes and characteristics. Thus, in the living body as an aggregation of such cells, its vector impedance locus does not show a half circle at variance with the case of measuring the lumped constant equivalent circuit, but shows a circular arc given in the Cole-Cole model.

[0004] Thus, the electrical impedance of the living body is generally represented by a circular arc-like locus shown in Fig. 2. In Fig. 2, x-axis represents a resistance component of the impedance, while y-axis represents a reactance component of the impedance. Since the reactance component of the bioelectrical impedance shows a negative value due to its capacitive property, the vector locus of the bioelectrical impedance is plotted on the underside of the real axis as shown in Fig. 2.

[0005] Referring to Fig. 3, R_0, R_{inf}, and Zc respectively indicate a resistance at 0 frequency, a resistance at infinite frequency and a bioelectrical impedance value at frequency Fc. As to R_0 and R_{inf}, they have only a resistance component because their reactance value is zero. At the frequency Fc, an absolute value of the reactance component reaches its maximum, and Zc is a bioelectrical impedance value at this frequency. As used herein, the frequency where the absolute value of the reactance component reaches its maximum is referred as to a characteristic frequency. Each body composition, such as a total body water, an intra-cellular water, an extra-cellular water, and a fat-free mass, is derived from the above values or approximate values thereof.

[0006] In a conventional method for determining the bioelectrical vector impedance locus based on bioelectrical impedances measured at a plurality of frequencies, the bioelectrical impedance is firstly measured in the range from a low frequency to a high frequency (i.e. from several kHz to about 1 MHz). Then, the aforementioned circular arc-like vector locus is derived from the measured data to calculate the above parameters.

[0007] Generally, the impedance vector measured by the conventional method is not provided in the form of a circular arc shown by a solid line in Fig. 2, but is represented in a curve-like locus shown by a dotted line in Fig. 2. This is supposedly resulted from a time lag in a signal transmission system which is influenced by both lengths of a bioelectrical impedance measuring cable and a measuring object. Practically, the least square approximation method would be applied to correct such an error and to make the vector impedance locus approximate to the circular arc. Making an approximate calculation requires multiplicity of iterative operations and thereby demands a high-speed arithmetic unit and a peripheral device thereof.

[0008] Thus, the conventional bioelectrical impedance measuring apparatus needs to employ the high speed arithmetic unit and the associated peripheral device. In addition, since it takes a long time for the measurement, a patient is forced to keep a specified posture for a long time. This has applied a certain burden to the patient.

[0009] An object of the present invention is to provide an improved bioelectrical impedance measuring method and a body composition measuring apparatus, which is capable of solving the problems of the prior art described above.

SUMMARY OF THE INVENTION

[0010] According to an aspect of the present invention, there is provided a bioelectrical impedance measuring method as defined in claim 1.

[0011] According to another aspect of the present invention, there is provided a body composition measuring apparatus as defined in claim 5.

[0012] Preferred embodiments are defined in the dependent claims.

[0013] The present invention will now be described in further detail with regard to preferred embodiments as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Fig. 1 shows an electrically equivalent circuit of a cell in a tissue,

Fig. 2 is a graphical representation of a bioelectrical vector impedance locus of a human body,

Fig. 3 is a graphical representation illustrating a relation between a point of characteristic frequency and points of 0 and infinite frequencies,

Fig. 4 is a schematic block diagram illustrating a general configuration of a body composition measuring apparatus for executing a bioelectrical imped-

ance measuring method according to an embodiment of the present invention,

Fig. 5 is a flow chart illustrating a measuring procedure of the apparatus of Fig. 4,

Fig. 6 exemplifies an input screen of the apparatus of Fig. 4,

Fig. 7 exemplifies a result screen of the apparatus of Fig. 4,

Fig. 8 is a schematic perspective view of a body composition measuring apparatus implementing a bioelectrical impedance measuring method according to another embodiment of the present invention,

Fig. 9 is a schematic block diagram illustrating a general configuration of the apparatus of Fig. 8, and

Fig. 10 is a flow chart illustrating a measuring procedure of the apparatus of Fig. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Referring to the attached drawings, especially to Figs. 4 to 10, aspects and embodiments of the present invention will be described in detail.

[0016] Fig. 4 illustrates a general configuration of a body composition measuring apparatus implementing a bioelectrical impedance measuring method according to an embodiment of the present invention. As shown in Fig. 4, the body composition measuring apparatus 1 of the present invention is generally segmented into two blocks, i.e. a block 1 and a block 2.

[0017] The block 1 is configured to mainly perform a control for the measurement, an arithmetic operation and an input/output of the data. The block 1 comprises: an arithmetic and control unit 2; a ROM 3 for storing constants and programs for an apparatus control and the arithmetic operation; a RAM 4 for temporarily storing a measured data, an arithmetic result, and data and programs read out from an external device; a nonvolatile auxiliary storage 5 allowing the measured data, the arithmetic result and a parameter regarding the measurement to be stored, read out or updated; an indicator 6 for indicating an information for operation, a condition during measurement, the measured data and the arithmetic result; an external input/output interface 7 for reading a parameter regarding the measurement for an external device and a control information or a control program for the measurement in order to input them into the present apparatus; an external interface terminal 8 for connecting the external input/output interface 7 to the external device; a key input device 9 for inputting a control command for the apparatus and a personal parameter of a person to be measured or a patient ; a clock device 10 for generating a time information for controlling a date and time of the measurement; a power source device 11 for supplying an electricity to each part of the present apparatus; and a power source terminal 12 for supplying the electricity to the power source device 11 from an external.

[0018] The block 2 is configured mainly to measure the bioelectrical impedance and to convert an analog signal thereof into a digital signal. The block 2 comprises an alternating signal generating device 20 for generating an alternating current signal with a frequency defined by a control program stored in the ROM 3 or the RAM 4; an alternating current output device 21 for applying to an object to be measured the alternating signal output from the alternating signal generating device 20 with an effective value defined by the control program stored in the ROM 3 or the RAM 4; a reference current detector 22 for detecting a current applied to the object to be measured and for outputting it as a reference current detection signal; alternating current output terminals 30 and 31 which are output terminals for applying to the object to be measured an alternating current supplied from the alternating current output device 21 through the reference current detector 22; an A/D converter 23 for converting an analog signal, which is an output of the reference current detector 22, to a digital signal; potential measuring terminals 32 and 33 which are input terminals for inputting potential signals from the object to be measured at two points thereof respectively; a potential difference detector 25 for outputting a differential signal of the potential signals between the potential measuring terminals 32 and 33; and an A/D converter 24 for converting an analog signal, which is an output of the potential difference detector 25, to a digital signal.

[0019] Fig. 4 shows a case where the bioelectrical impedance is measured between a hand and a foot of the patient or the object to be measured by the use of the apparatus having a configuration described above. As for a place to which an electrode for measurement is attached, a well-known conventional manner is employed. As for the hand, an electrode 50 for applying a measuring current connected to the alternating current output terminals 30 via a measuring cable 40 is attached to a back of the hand at a place close to a finger joint. In addition, a potential measuring electrode 52 connected to the potential measuring terminals 32 via a measuring cable 42 is attached close to a wrist joint. As for the foot, an electrode 51 for applying a measuring current connected to the alternating current output terminals 31 via a measuring cable 41 is attached to an instep of the foot at a place close to a finger joint. In addition, a potential measuring electrode 53 connected to the potential measuring terminal 33 via a measuring cable 43 is attached close to an ankle joint.

[0020] Then a measuring procedure and an operation of the present embodiment will be generally described with reference to the flow chart shown in Fig. 5.

[0021] When a power switch of the apparatus being turned on at step S1, the apparatus is initialized (step S2) and simultaneously an initial screen is indicated on the indicator 6 for a few second (step S3). Then, at step S4, a screen for inputting a personal parameter shown in Fig. 6 is indicated on the indicator 6 to enter a wait

state. At step S5, an identification number of a person to be measured and the personal parameters thereof including a sex, a height, a body weight and an age are input through the key input device 9. The present embodiment is configured, however, such that the measuring can be performed even if these parameters are not set. When the personal parameters are not set, however, an arithmetic operation for calculating a body composition is not executed as described later (step 8).

[0022] At step S6, a measuring operation of the bioelectrical impedance starts when a measuring start key is pushed whether or not the personal parameters have been set. It is a matter of course that the electrode for the measurement should have been attached to the person to be measured and should have been connected to the apparatus before starting the measurement.

[0023] The bioelectrical impedance is measured according to a following procedure (step S7).

[0024] An output signal frequency is set by the alternating signal generating device 20 based on a measurement control parameter stored in advance in the ROM 3 or on the measurement control parameter set in the RAM 4 through the auxiliary storage 5 or the external input/output interface 7. An output signal from the alternating signal generating device 20 is input to the alternating current output device 21.

[0025] The alternating current output device 21 is composed of a constant current output circuit whose current value can be optionally set. When the output current value is set based on the measurement control parameter, the alternating current output therefrom is applied to the person to be measured through the reference current detector 22, the alternating current output terminals 30 and 31, the measurement cables 40 and 41 connected to respective terminals, and the electrodes 50 and 51 for applying a measuring current.

[0026] At that time, the current applied to the person to be measured is detected by the reference current detector 22. The detected output taking the form of analog signal is converted to the digital signal by the A/D converter 23, and the resulting signal is stored in the RAM 4. Simultaneously, potential signals are input through the potential measuring electrodes 52 and 53 attached to the person to be measured, the measuring cables 42 and 43 connected to respective electrodes, and the potential measuring terminals 32 and 33 connected to respective measuring cables, to the potential difference detector 25. The potential difference detector 25 in turn outputs the potential difference signal, which corresponds to the difference between the potentials input to the potential difference detector, into the A/D converter 24. The A/D converter 24 converts the input analog signal into the digital signal and the resulting signal is stored in the RAM 4.

[0027] This process is applied based on the measurement control parameter to each of the alternating currents with the first, second and third frequencies respectively. To achieve a higher accuracy, the first, second and third frequencies should preferably be one at which the resistance component reaches approximately its maximum, one at which the resistance component reaches approximately its minimum and one at which the absolute value of the reactance component reaches approximately its maximum. To suppress adverse influence of stray capacitances and foreign noises to simplify the analog circuit, as for the first, second and third frequencies, preferably they are selected to be as low as possible, e.g. in the range of 1 kHz to 100 kHz. For example, the first frequency is 4 kHz, the second frequency is 16 kHz and the third frequency is 64 kHz.

[0028] Then the vector impedance locus and the parameters associated thereto are calculated based on the measured values by the alternating current with respective frequencies.

[0029] According to an assumption that the vector impedance locus derived is a circular arc, the bioelectrical impedance values Z1, Z2 and Z3 measured respectively at the first, second and third frequencies (hereinafter referred to as F1, F2 and F3) are on a circular arc of a certain circle as shown in Fig. 3. Herein, a real axis (axis of abscissa) and an imaginary axis (axis of ordinate) of the vector impedance plane are described as an X-axis and a Y-axis respectively. Therefore, an equation of the circle having these three points thereon is described as:

$$(X - a)^2 + (Y - b)^2 = r^2 \qquad (1)$$

where, "a" is X coordinate of the center of the circle, "b" is Y coordinate of the center of the circle, and "r" is a radius of the circle. The values of "a", "b" and "c" can be calculated by substituting the measured values of the bioelectrical impedance vector Z1, Z2 and Z3 at the frequencies F1, F2 and F3 in the equation (1).

[0030] Intersections of the circle and X-axis or the real axis are determined by the equation (1) as:

$$X = a \pm \sqrt{(r^2 - b^2)}$$

wherein, since $R_0 > R_{inf}$,

$$R_0 = a + \sqrt{(r^2 - b^2)}$$

$$R_{inf} = a - \sqrt{(r^2 - b^2)}$$

[0031] Accordingly, Re and Ri of the equivalent circuit of Fig. 1 are described as:

$$Re = R_0$$

$$Ri = R_0 \cdot R_{inf} / (R_0 - R_{inf})$$

[0032] Since the impedance vector Zc at the characteristic frequency Fc is defined by a point where the reactance or the imaginary axis component, that is, the absolute value of Y-axis component, takes a maximum value, X coordinate as a real axis component and Y coordinate as an imaginary axis component of the impedance vector Zc are determined as:

$$X = a, \qquad Y = b - r$$

and thereby the impedance vector Zc is represented as:

$$Zc = Rc + jXc = a + j(b - r)$$

where Rc is a resistance component of Zc, and Xc is a reactance component of Zc.

[0033] According to Cole-Cole model described in DESCRIPTION OF THE PRIOR ART, the impedance vector at a frequency ω is represented as:

$$Z(\omega) = R_{inf} + (R_0 - R_{inf}) / (1 + (j\omega\ \tau)^{\beta})$$

where, $Z(\omega)$ is the impedance vector at ω, and τ and β are constants.

[0034] When $\tau = 1 / \omega c$,

$$Z(\omega) = R_{inf} + (R_0 - R_{inf}) / (1 + (j\omega/\omega c)^{\beta})$$

where $\omega c = 2\pi Fc$.

[0035] Fc and β can be calculated also based on these relations and a data on the circle.

[0036] Then the body composition values including the extra-cellular water (ECW), the intra-cellular water (ICW), a ratio of the extra-cellular water to the intra-cellular water, the total body water (TBW), the fat free mass (FFM), body fat mass (FM) and the body fat rate are calculated based on the vector impedance locus and the associated parameters, such as R_0, R_{inf}, Ri, Zc, Fc or the like, which are calculated beforehand (step S9). When the personal parameter has not been set, this process is omitted as described above.

[0037] Then the measured results and other results calculated based thereon are indicated on the indicator 6 (step S10). An example of the indication is shown in Fig. 7. Further, based on the measurement control parameter, the measured results, the arithmetic results, the parameters regarding the measurement or the like are transmitted to the external device through the external input/output interface 7 (step S11) or are stored in the auxiliary storage 5 (step S12).

[0038] After the above steps are completed, the process enters a wait state (step S13). When a re-measurement key is pushed (step S14), the measurement is performed again, and when a new-measurement key is pushed (step S15), the process returns to the step for personal parameter input and enters a wait state.

[0039] Fig. 8 is a schematic perspective view of a body composition measuring apparatus for executing a bioelectrical impedance measuring method according to another embodiment of the present invention, and Fig. 9 is a block diagram illustrating a general configuration of this apparatus. The apparatus of the present invention is, as shown in Fig. 8, a simplified apparatus incorporating a weight scale therein.

[0040] Main functional sections of the present apparatus 100 will be described with reference especially to Fig. 9.

[0041] The apparatus 100 comprises a microcomputer 102 having a functions of CPU, ROM, RAM, timer, I/O port or the like; an indicator section 103 for indicating a personal parameter setting of a person to be measured, a measured result, a condition during measurement or the like; a key switch 104 for inputting the personal parameter, and for selecting the personal parameter stored in a nonvolatile memory 106 or the like; an external input/output interface 105 for performing input/output operation with an external device; the nonvolatile memory 106 for storing a measurement control parameter, the personal parameter or the like; a filter circuit 110 for shaping an output signal from the microcomputer 102 into a signal to be applied to an living body; an alternating current output circuit 111 for applying an output signal from the filter circuit 110 to the person to be measured, with a constant effective value; a reference resistor 112 connected to an end of an output of the alternating current output circuit 111, for detecting a current applied to the person to be measured; measuring current supply electrodes 120 and 121 connected through the reference register 112; a differential amplifier 113 for detecting a potential difference between ends of the reference resistor 112; a potential measuring electrodes 122 and 123 for detecting potentials of the person to be measured at two points thereof; a differential amplifier 114 connected to the potential measuring electrodes 122 and 123 for detecting a potential difference therebetween; a weight sensor 115 for detecting a loading; an amplifier 116 for amplifying a signal from the weight sensor 115; a switching unit 117 for selectively outputting one of the outputs from the differential amplifiers 113, 114 and that from the amplifier 116 based on the control of the microcomputer 102; and an A/D converter 118 for converting an analog signal output from the switching unit 117 into a digital signal to output it to the microcomputer 102.

[0042] Then an operation and an operating procedure of the present embodiment will be described with reference to Fig. 10, which is a flow chart generally illustrating the operation and the operating procedure of the

present embodiment.

[0043] The operation of the present apparatus starts upon the key switch being pushed (step S1). The key switch used in the present embodiment includes eight key switches consisting of three key switches, that is, SET key, UP key and DOWN key used for setting the personal parameter; four key switches from No. 1 to No. 4 memory number key switches; and one key switch for performing only a body weight measurement. The operation of the present apparatus is branched into three ways depending on the kinds of the key switches pushed for starting the operation.

1. When the body weight key is pushed to start the operation (step S2):

[0044] Only the body weight measurement is performed (step S3), a result thereof is indicated on the indicator section 103 (step S4), the indication is turned off after a certain period, and then the process enters a wait state (step S5) to wait a next key switch input.

[0045] When the body weight key is not pushed at step S2, it is judged whether any one of the setting keys (SET key, UP key, DOWN key) is pushed (step S6).

[0046] When none of the setting keys is pushed, it is judged whether any one of the No. 1 to No. 4 memory number keys is pushed (step S7). When none of the No. 1 to No. 4 memory number key switches is pushed, the process enters the wait state (step S8) to wait the next key switch input.

2. When the memory number key switch is pushed to start the operation (step S9);

[0047] The operation depends whether the parameter has been set or not.

2-1. When the personal parameter corresponding to the pushed memory number has not been stored:

[0048] The same operation with that described in the following item 3. "When any one of the setting keys is pushed to start the operation" is performed. The personal parameter set at that time is stored as a data for the pushed memory number.

2-2. When the personal parameter corresponding to the pushed memory number has been stored:

[0049] The personal parameter corresponding to the pushed memory number stored in the nonvolatile memory 106 is indicated on the indicator section 103 for a certain period and then the body weight is measured. At that time, in order to measure the body weight, the signal to be supplied from the microcomputer 102 to the filter circuit 110 when the impedance is to be measured is stopped and the switching unit 117 is controlled by the microcomputer 102 so that the output from the amplifier 116 may be selected as the input to the A/D converter 118.

[0050] After the body weight is measured, the bioelectrical impedance is measured. At that time, according to the measurement control parameter having been written beforehand in the ROM in the microcomputer 102, the signal is supplied from the microcomputer 102 to the filter circuit 110 and the output therefrom is input to the alternating current output circuit 111. The output from the alternating current output circuit 111 is applied to the person to be measured through the reference resistor 112 connected to one end of the alternating current output circuit 111. Since the potential difference signal of the reference resistor 112 and the potential difference signal between two points of the living body are output respectively from the differential amplifiers 113 and 114, they are converted into the control signal for the microcomputer 102 and are output to the microcomputer 102. The measurement of the bioelectrical impedance described above is performed based on the measurement control parameter for each of three frequencies including the first, the second and the third frequencies (step S10).

[0051] An arithmetic processing is performed using the measured bioelectrical impedance data to determine R_0, R_{inf} and Zc and further to calculate Re and Ri in the same manner as described with reference to the embodiment mentioned above. The extra-cellular water, the intra-cellular water, the total body water, the fat free mass, and the body fat mass are determined based on these calculated results (step S11).

[0052] The results of the arithmetic processing are indicated on the indicator section 103 (step S12), the indication is turned off after a certain period (step 13), and the process enters the wait state (step S14) to wait the next key switch input.

3. When any one of the setting keys is pushed at step S6 to start the operation:

[0053] An indication for setting the personal parameter is indicated on the indicator section 103 (step S15). In the present embodiment, items of the personal parameter to be set are two items, that is, the sex and the height. Each item of the personal parameters is to be set according to the indication on the indicator section 103. When the setting value is input, the UP key and the DOWN key are used to select a selection item and a value to be set. The sex and the value of the height are confirmed and set by pushing the SET key when being input respectively.

[0054] At that time, in case where the process branches off from the above item 2-1 "When the personal parameter corresponding to the pushed memory number has not been stored" to the present setting step of the personal parameter, the personal parameter set herein is automatically stored in the nonvolatile memory 106 as a data for the memory number having been pushed

(step S18), the indication is turned off after a certain period, and the process enters the wait state (step S19) to wait the next key switch input.

[0055] In other cases, the process enters the wait state to wait the key input for a certain period (step S16).

[0056] When the memory number key switch is pushed during the certain period (step S17), the personal parameter set herein is stored in the nonvolatile memory 106 as a data for the pushed memory number (step S18), the indication is turned off after a certain period, and the process enters the wait state (step S19) to wait the next key switch input.

[0057] Further, when the SET key is pushed during the certain period (step 20) or when the certain period has passed to end the wait state for waiting the next key input (step S21), the operation described in the above item 2 "When the memory number key switch is pushed to start the operation" (step S10 and the followings thereof) is performed.

[0058] Although the external input/output interface 105 is not referred to in the description of the main operation and the operating procedure, in the present embodiment, this device is added when it is necessary and has functions to output the measured result of the bioelectrical impedance and the results derived therefrom through the arithmetic processing and to input a measurement control command or the parameters from an external device into the present apparatus.

[0059] Since the number of frequencies used for the measurement is limited to three, an analog circuit section for measuring the impedance can be made simpler comparing with the conventional one.

[0060] Since the present apparatus does not require such a lot of iterative operations for constructing the vector impedance locus as the conventional one, a high speed arithmetic unit and a peripheral device thereof are not necessary. In addition, the period for the measurement is made short, which allows a user (patient) to use it comfortably.

[0061] Since the present apparatus is simplified as a whole comparing with the conventional one, the apparatus can be made compact and the cost thereof can be reduced.

[0062] Since the compactness of the present apparatus allows it to be driven by battery, only a small area is necessary to install it and this makes it possible to be carried easily.

[0063] Further, since the present apparatus can be made compact and can be manufactured at low cost, as shown in above another embodiment, it can be spread in the same manner as of the conventional body fat meter with single frequency measurement system while allowing more accurate measurement of body fat comparing with the conventional one with single frequency measurement system.

[0064] That is, when the present apparatus is to be configured incorporating a body weight measuring section therein, what has to be made is only to add a small modification to a circuit section of the conventional body weight scale with body fat meter.

Claims

1. A bioelectrical impedance measuring method for measuring a bioelectrical Impedance of a patient by applying an alternating current to a body of said patient based on a bloelectrical impedance method, said method comprising the steps of:

   determining a first bioelectrical impedance value by a measurement using the alternating current having a first frequency;
   determining a second bioelectrical impedance value by a measurement using the alternating current having a second frequency;
   determining a third bioelectrical impedance value by a measurement using the alternating current having a third frequency; and
   determining an vector impedance locus by assuming that the vector impedance locus derived is an circular arc and substituting the determined first, second and third bioelectrical impedance values in an equation of the circle, and solving simultaneous equations including three equations to derive X coordinate of the center of the circle, Y coordinate of the center of the circle and the radius of the circle, to determine bioelectrical impedance values at 0 frequency and at an infinite frequency from intersections of the circle and the X-axis of the vector impedance plane.

2. A bioelectrical impedance measuring method in accordance with claim 1, wherein the bioelectrical impedance value R_0 at the 0 frequency is described as $R_0 = a + \sqrt{(r^2 - b^2)}$ and the bioelectrical impedance value R_{inf} at the infinite frequency is described as $R_{inf} = a - \sqrt{(r^2 - b^2)}$, where X coordinate of the center of the circle forming said circular arc is a, Y coordinate of the center of the circle Is b, and the radius of the circle is r.

3. A bioelectrical impedance measuring method in accordance with claim 1, wherein all said first, second and third frequencles are in the range of 1 kHz to 100 kHz.

4. A bioelectrical impedance measuring method In accordance with claim 1 wherein the first, second and third frequencies are one at which the resistance component reaches approximately its maximum, one at which the resistance component reaches approximately its minimum and one at which the absolute value of the reactance component of said bioelectrical impedance reaches approximately its

maximum.

5. A body composition measuring apparatus for measuring a bioelectrical impedance of a patient by applying an alternating current to a body of said patient based on a bioelectrical impedance method, said body composition measuring apparatus comprising:

an alternating current generating device capable of generating at least three kinds of alternating currents with different frequencies;
a measuring device which determines a first bioelectrical impedance value, a second bioelectrical impedance value and a third bioelectrical impedance value based on measurements using the alternating current having a first frequency, the alternating current having a second frequency and the alternating current having a third frequency respectively, among said alternating currents generated by said alternating current generating device;
an arithmetic device which derives an vector impedance locus from only said first, second and third bioelectrical impedance value, assuming that the vector impedance locus derived is an circular arc, to determine bioelectrical impedance values at 0 frequency and at an infinite frequencies from intersections of the circle and the X-axis of the vector impedance plane; and
a judging device which judges a body composition of said patient based on said bioelectrical impedance values determined by said arithmetic device.

6. A body composition measuring apparatus in accordance with claim 5, wherein the bioelectrical impedance value R_0 at the 0 frequency is described as $R_0 = a + \sqrt{(r^2 - b^2)}$ and the bioelectrical impedance value R_{inf} at the infinite frequency is described as $R_{inf} = a - \sqrt{(r^2 - b^2)}$, where X coordinate of the center of the circle forming said circular arc is a, Y coordinate of the center of the circle is b, and the radius of the circle is r.

7. A body composition measuring apparatus in accordance with claim 5, further comprising:

an input device which sets a personal parameter including a body weight of said patient; and
an indicating device which indicates information regarding said body composition judged by said judging device, wherein said judging device takes said personal parameter input by said input device into account when judging said body composition of said patient.

8. A body composition measuring apparatus in accordance with claim 5, further comprising:

a body weight measuring device which measures a body weight of said patient;
an input device which sets a personal parameter other than said body weight of said patient, and an indicating device for indicating information regarding said body composition of said patient Judged by said judging device, wherein said judging device takes said body weight measured by said body weight measuring device and said personal parameter input by said input device into account when judging said body composition of said patient.

9. A body composition measuring apparatus In accordance with either of claim 5 to 8, wherein all said first, second and third frequencies are in the range of 1 kHz to 100 kHz.

10. A body composition measuring apparatus in accordance with either of claims 5 to 8 wherein the first, second and third frequencies are one at which the resistance component reaches approximately its maximum, one at which the resistance component reaches approximately its minimum and one at which the absolute value of the reactance component of said bioelectrical impedance reaches approximately its maximum.

11. A body composition measuring apparatus in accordance with either of claim 5 to 8, wherein said body composition is at least one of an extra-cellular water, an intra-cellular water, a total body water, a fat free mass, and a body fat mass.

Patentansprüche

1. Verfahren zur Messung der bioelektrischen Impedanz zum Messen einer bioelektrischen Impedanz eines Patienten durch Anlegen eines Wechselstroms an einen Körper des Patienten, basierend auf einem bioelektrischen Impedanzverfahren, wobei das Verfahren die Schritte umfaßt:

Bestimmen eines ersten, bioelektrischen Impedanzwerts durch eine Messung unter Verwendung des Wechselstroms, der eine erste Frequenz aufweist;
Bestimmen eines zweiten, bioelektrischen Impedanzwerts durch eine Messung unter Verwendung des Wechselstroms, der eine zweite Frequenz aufweist;
Bestimmen eines dritten, bioelektrischen Impedanzwerts durch eine Messung unter Verwendung des Wechselstroms, der eine dritte Fre-

quenz aufweist; und
Bestimmen eines Vektorimpedanzorts durch Annahme, daß der abgeleitete Vektorimpedanzort ein Kreisbogen ist, und Substituieren des bestimmten ersten, zweiten und dritten bioelektrischen Impedanzwerts in einer Gleichung des Kreises und Lösen von simultanen Gleichungen, beinhaltend drei Gleichungen, um eine X-Koordinate des Zentrums des Kreises, eine Y-Koordinate des Zentrums des Kreises und den Radius des Kreises abzuleiten, um bioelektrische Impedanzwerte bei 0-Frequenz und bei einer infiniten bzw. unendlichen Frequenz aus Schnitten des Kreises und der X-Achse der Vektorimpedanzebene zu bestimmen.

2. Verfahren zur Messung der bioelektrischen Impedanz nach Anspruch 1, worin der bioelektrische Impedanzwert R_0 an der 0-Frequenz als $R_0 = a + \sqrt{(r^2 - b^2)}$ beschrieben ist und der bioelektrische Impedanzwert R_{inf} an der unendlichen Frequenz als $R_{inf} = a - \sqrt{(r^2 - b^2)}$ beschrieben ist, worin X-Koordinate des Zentrums des Kreises, der den Kreisbogen ausbildet, a ist, die Y-Koordinate des Zentrums des Kreises b ist, und der Radius des Kreises r ist.

3. Verfahren zur Messung der bioelektrischen Impedanz nach Anspruch 1, worin alle der ersten, zweiten und dritten Frequenz in dem Bereich von 1 kHz bis 100 kHz liegen.

4. Verfahren zur Messung der bioelektrischen Impedanz nach Anspruch 1, worin die erste, zweite und dritte Frequenz eine ist, bei welcher die Widerstandskomponente ungefähr ihr Maximum erreicht, eine ist, bei welcher die Widerstandskomponente ungefähr ihr Minimum erreicht, und eine ist, bei welcher der Absolutwert der Reaktanzkomponente der bioelektrischen Impedanz ungefähr ihr Maximum erreicht.

5. Vorrichtung zur Messung einer Körperzusammensetzung zum Messen einer bioelektrischen Inpedanz eines Patienten durch Anlegen eines Wechselstroms an einen Körper des Patienten basierend auf einem bioelektrischen Impedanzverfahren, wobei die Vorrichtung zur Messung der Körperzusammensetzung umfaßt:

eine Vorrichtung zum Erzeugen eines Wechselstroms, welche fähig ist, wenigstens drei Arten von Wechselströmen mit unterschiedlichen Frequenzen zu generieren bzw. zu erzeugen;
eine Meßvorrichtung, welche einen ersten, bioelektrischen Impedanzwert, einen zweiten, bioelektrischen Impedanzwert und einen dritten, bioelektrischen Impedanzwert, basierend auf Messungen verwendend den Wechselstrom, der eine erste Frequenz aufweist, den Wechselstrom, der eine eine zweite Frequenz aufweist, und den Wechselstrom, der eine dritte Frequenz aufweist, unter den Wechselströmen bestimmt, die durch die Vorrichtung zum Erzeugen des Wechselstroms erzeugt sind;
eine arithmetische Vorrichtung bzw. Rechenvorrichtung, welche einen Vektorimpedanzort nur aus dem ersten, zweiten und dritten bioelektrischen Impedanzwert unter der Annahme ableitet, daß der abgeleitete Vektorimpedanzort ein Kreisbogen ist, um bioelektrische Impedanzwerte bei 0-Frequenz und bei einer infiniten bzw. unendlichen Frequenz aus Schnitten des Kreises und der X-Achse der Vektorimpedanzebene zu bestimmen; und
eine Beurteilungs- bzw. Bestimmungsvorrichtung, welche eine Körperzusammensetzung des Patienten basierend auf den bioelektrischen Impedanzwerten, die durch die arithmetische Vorrichtung bestimmt sind, abschätzt bzw. beurteilt.

6. Vorrichtung zur Messung einer Körperzusammensetzung nach Anspruch 5, worin der bioelektrische Impedanzwert R_0 an der 0-Frequenz als $R_0 = a + \sqrt{(r^2 - b^2)}$ beschrieben ist und der bioelektrische Impedanzwert R_{inf} an der unendlichen Frequenz als $R_{inf} = a - \sqrt{(r^2-b^2)}$ beschrieben ist, worin die X-Koordinate des Zentrums des Kreises, der den Kreisbogen ausbildet, a ist, die Y-Koordinate des Zentrums des Kreises b ist und der Radius des Kreises r ist.

7. Vorrichtung zur Messung einer Körperzusammensetzung nach Anspruch 5, weiters umfassend:

eine Eingabevorrichtung, welche einen persönlichen Parameter, beinhaltend ein Körpergewicht des Patienten, festlegt; und
eine Anzeigevorrichtung, welche Information betreffend die Körperzusammensetzung anzeigt, die durch die Beurteilungsvorrichtung bestimmt ist, worin die Beurteilungsvorrichtung den persönlichen Parameter, der durch die Eingabevorrichtung eingegeben ist, in Betracht zieht bzw. berücksichtigt, wenn die Körperzusammensetzung des Patienten bestimmt bzw. beurteilt wird.

8. Vorrichtung zur Messung einer Körperzusammensetzung nach Anspruch 5, weiters umfassend:

eine Körpergewichtmeßvorrichtung, welche ein Körpergewicht des Patienten mißt;
eine Eingabevorrichtung, welche einen persönlichen Parameter, der nicht das Körpergewicht des Patienten ist, festlegt, und eine Anzeige-

einrichtung zum Anzeigen von Information betreffend die Körperzusammensetzung des Patienten, die durch die Bestimmungs- bzw. Beurteilungseinrichtung bestimmt bzw. beurteilt ist, worin die Beurteilungsvorrichtung das Körpergewicht, das durch die Körpergewichtsmeßvorrichtung gemessen ist, und den persönlichen Parameter, der durch die Eingabevorrichtung eingegeben ist, in Betracht zieht, wenn die Körperzusammensetzung des Patienten beurteilt wird.

9. Vorrichtung zur Messung einer Körperzusammensetzung nach einem der Ansprüche 5 bis 8, worin alle der ersten, zweiten und dritten Frequenz in dem Bereich von 1 kHz bis 100 kHz liegen.

10. Vorrichtung zur Messung einer Körperzusammensetzung nach einem der Ansprüche 5 bis 8, worin die erste, zweite und dritte Frequenz eine ist, bei welcher die Widerstandskomponente ungefähr ihr Maximum erreicht, eine ist, an welcher die Widerstandskomponente ungefähr ihr Minimum erreicht, und eine ist, an welcher der Absolutwert der Reaktanzkomponente der bioelektrischen Impedanz ungefähr ihr Maximum erreicht.

11. Vorrichtung zur Messung einer Körperzusammensetzung nach einem der Ansprüche 5 bis 8, worin die Körperzusammensetzung wenigstens eine aus einem extrazellulären Wasser, einem intrazellulären Wasser, einem Gesamtkörperwasser, einer fettfreien Masse und einer Körperfettmasse ist.

Revendications

1. Procédé de mesure d'impédance bioélectrique, permettant de mesurer l'impédance bioélectrique d'un patient en appliquant un courant alternatif au corps dudit patient sur la base d'un procédé d'impédance bioélectrique, ledit procédé comprenant les opérations suivantes :

déterminer une première valeur d'impédance bioélectrique par une mesure utilisant un courant alternatif ayant une première fréquence ;
déterminer une deuxième valeur d'impédance bioélectrique par une mesure utilisant un courant alternatif ayant une deuxième fréquence ;
déterminer une troisième valeur d'impédance bioélectrique par une mesure utilisant un courant alternatif ayant une troisième fréquence ; et
déterminer un lieu d'impédance vectoriel en supposant que le lieu d'impédance vectoriel déduit est un arc circulaire et en substituant les première, deuxième et troisième valeurs d'impédance bioélectrique déterminées dans une équation du cercle et en résolvant des équations simultanées qui comportent trois équations afin de déduire la coordonnée X du centre du cercle, la coordonnée Y du centre du cercle et le rayon du cercle, et ainsi déterminer les valeurs d'impédance bioélectrique à la fréquence nulle et à une fréquence infinie à partir des intersections du cercle et de l'axe X du plan d'impédance vectoriel.

2. Procédé de mesure d'impédance bioélectrique selon la revendication 1, où la valeur d'impédance bioélectrique R_0 à la fréquence nulle est décrite comme étant $R_0 = a + \sqrt{(r^2-b^2)}$ et la valeur d'impédance bioélectrique R_{inf} à fréquence infinie est décrite comme étant $R_{inf} = a - \sqrt{(r^2 - b^2)}$, où la coordonnée X du centre du cercle formant l'arc circulaire est <u>a</u>, la coordonnée Y du centre du cercle est <u>b</u>, et le rayon du cercle est <u>r</u>.

3. Procédé de mesure d'impédance bioélectrique selon la revendication 1, où lesdites première, deuxième et troisième fréquences sont toutes comprises dans l'intervalle de 1 kHz à 100 kHz.

4. Procédé de mesure d'impédance bioélectrique selon la revendication 1, où les première, deuxième et troisième fréquences sont une fréquence pour laquelle la composante de résistance atteint approximativement son maximum, une fréquence pour laquelle la composante de résistance atteint approximativement son minimum, et une fréquence pour laquelle la valeur absolue de la composante de réactance de ladite impédance bioélectrique atteint approximativement son maximum.

5. Appareil de mesure de la composition d'un corps servant à mesurer l'impédance bioélectrique d'un patient par application d'un courant alternatif au corps dudit patient sur la base d'un procédé d'impédance bioélectrique, ledit appareil de mesure de la composition du corps comprenant :

un dispositif générateur de courants alternatifs, qui peut produire au moins trois sortes de courants alternatifs ayant des fréquences différentes ;
un dispositif de mesure qui détermine une première valeur d'impédance bioélectrique, une deuxième valeur d'impédance bioélectrique et une troisième valeur d'impédance bioélectrique sur la base de mesures utilisant un courant alternatif ayant une première fréquence, un courant alternatif ayant une deuxième fréquence et un courant alternatif ayant une troisième fréquence, respectivement, parmi lesdits courants alternatifs produits par ledit dispositif gé-

nérateur de courants alternatifs ;
un dispositif arithmétique, qui déduit un lieu d'impédance vectoriel à partir des seules première, deuxième et troisième valeurs d'impédance bioélectrique, si l'on suppose que le lieu d'impédance vectoriel déduit est un arc de cercle, afin de déterminer les valeurs d'impédance bioélectrique à la fréquence nulle et à une fréquence infinie à partir des intersections du cercle et de l'axe X du plan d'impédance vectoriel ; et
un dispositif de prise de décision qui détermine la composition du corps dudit patient sur la base desdites valeurs d'impédance bioélectrique déterminées par ledit dispositif arithmétique.

6. Appareil de mesure de la composition d'un corps selon la revendication 5, où la valeur d'impédance bioélectrique R_0 pour la fréquence nulle est décrite comme étant $R_0 = a + \sqrt{(r^2 - b^2)}$ et la valeur d'impédance bioélectrique R_{inf} pour la fréquence infinie est décrite comme étant $R_{inf} = a - \sqrt{(r^2 - b^2)}$, où la coordonnée X du centre du cercle formant ledit arc de cercle est <u>a</u>, la coordonnée Y du centre du cercle est <u>b</u>, et le rayon du cercle est <u>r</u>.

7. Appareil de mesure de la composition d'un corps selon la revendication 5, comprenant en outre :

un dispositif d'entrée qui fixe un paramètre personnel comportant le poids du corps dudit patient ; et
un dispositif indicateur qui indique des informations concernant ladite composition du corps déterminée par ledit dispositif de prise de décision, où ledit dispositif de prise de décision prend en compte ledit paramètre personnel introduit par ledit dispositif d'entrée lors de la détermination de ladite composition du corps dudit patient.

8. Appareil de mesure de la composition d'un corps selon la revendication 5, comprenant en outre :

un dispositif de mesure de poids du corps, qui mesure le poids du corps dudit patient ;
un dispositif d'entrée qui fixe un paramètre personnel autre que ledit poids du corps dudit patient, et un dispositif indicateur servant à indiquer des informations concernant ladite composition du corps dudit patient déterminée par ledit dispositif de prise de décision, où ledit dispositif de prise de décision prend en compte ledit poids du corps mesuré par ledit dispositif de mesure du poids du corps et ledit paramètre personnel introduit par ledit dispositif d'entrée lors de la détermination de ladite composition du corps dudit patient.

9. Appareil de mesure de la composition d'un corps selon une quelconque des revendications 5 à 8, où lesdites première, deuxième et troisième fréquences sont toutes dans l'intervalle de 1 kHz à 100 kHz.

10. Appareil de mesure de la composition d'un corps selon l'une quelconque des revendications 5 à 8, où lesdites première, deuxième et troisième fréquences sont une fréquence pour laquelle la composante de résistance atteint approximativement son maximum, une fréquence pour laquelle la composante de résistance atteint approximativement son minimum, et une fréquence pour laquelle la valeur absolue de la composante de réactance de ladite impédance bioélectrique atteint approximativement son maximum.

11. Appareil de mesure de la composition d'un corps selon l'une quelconque des revendications 5 à 8, où ladite composition du corps est au moins l'une parmi les suivantes, à savoir l'eau extracellulaire, l'eau intracellulaire, l'eau corporelle totale, la masse non grasse, et la masse grasse du corps.

FIG. 1

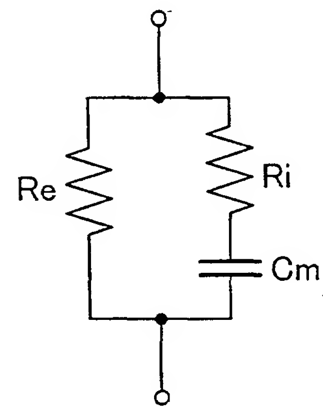

Re
Ri
Cm

FIG. 2

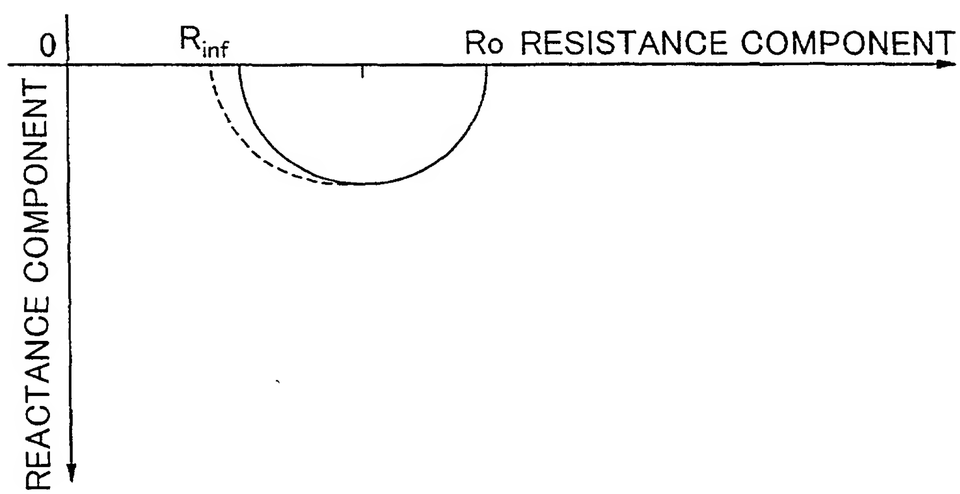

0
R_{inf}
Ro
RESISTANCE COMPONENT
REACTANCE COMPONENT

FIG. 3

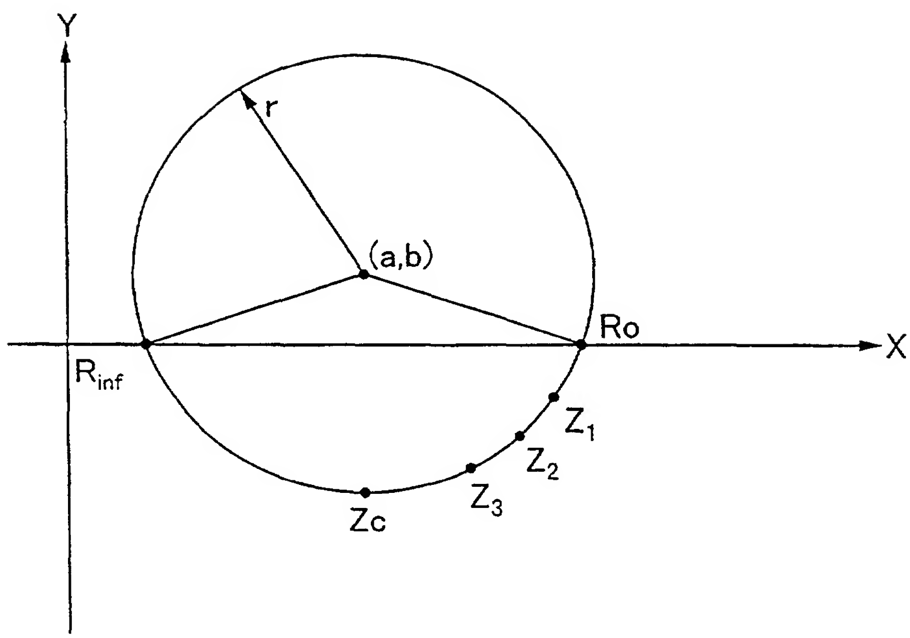


FIG. 4

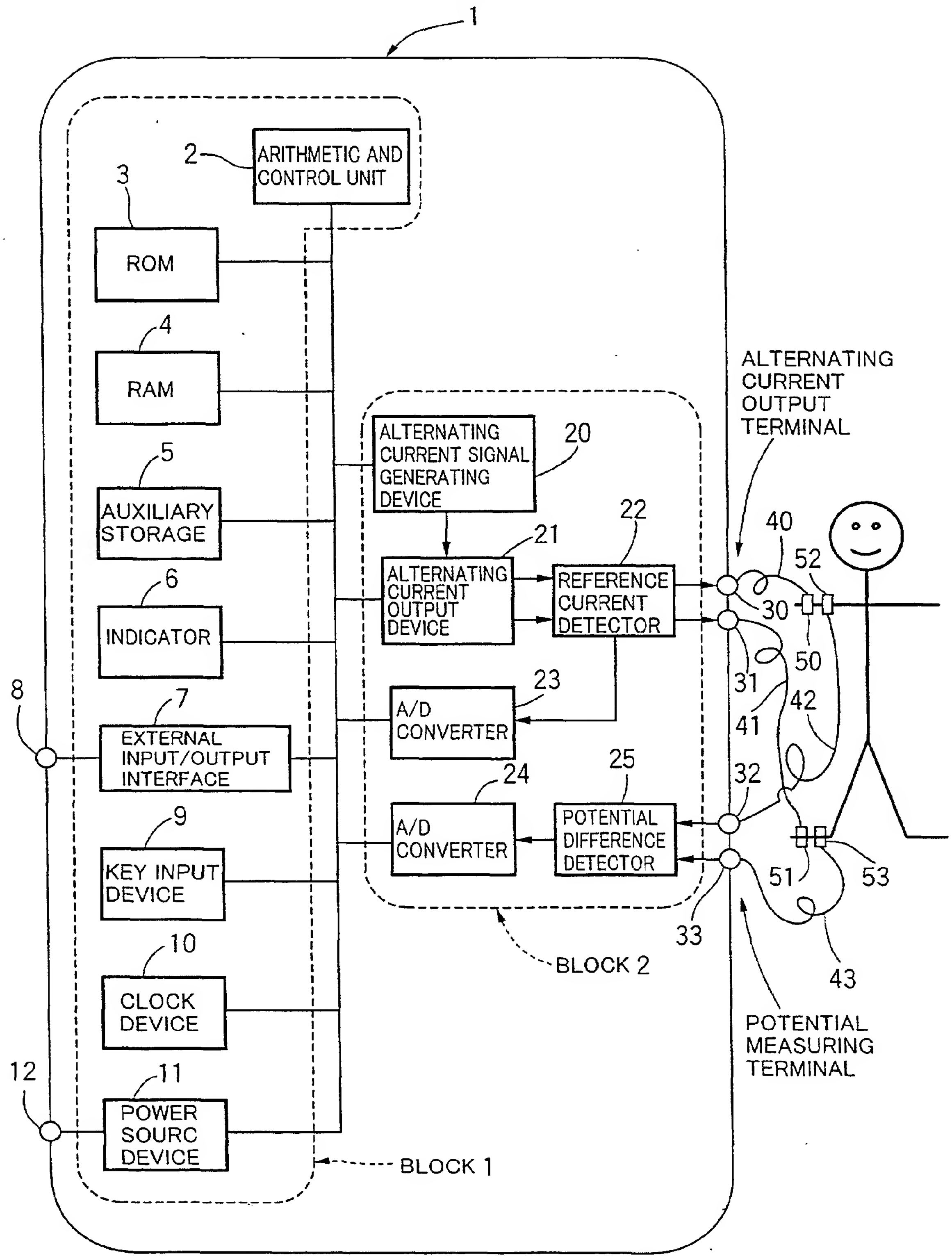

1
2
ARITHMETIC AND CONTROL UNIT
3
ROM
4
RAM
5
AUXILIARY STORAGE
6
INDICATOR
7
EXTERNAL INPUT/OUTPUT INTERFACE
8
9
KEY INPUT DEVICE
10
CLOCK DEVICE
11
POWER SOURC DEVICE
12
BLOCK 1
ALTERNATING CURRENT SIGNAL GENERATING DEVICE
20
ALTERNATING CURRENT OUTPUT DEVICE
21
REFERENCE CURRENT DETECTOR
22
A/D CONVERTER
23
A/D CONVERTER
24
POTENTIAL DIFFERENCE DETECTOR
25
BLOCK 2
ALTERNATING CURRENT OUTPUT TERMINAL
30
31
32
33
40
41
42
43
50
51
52
53
POTENTIAL MEASURING TERMINAL

FIG. 5

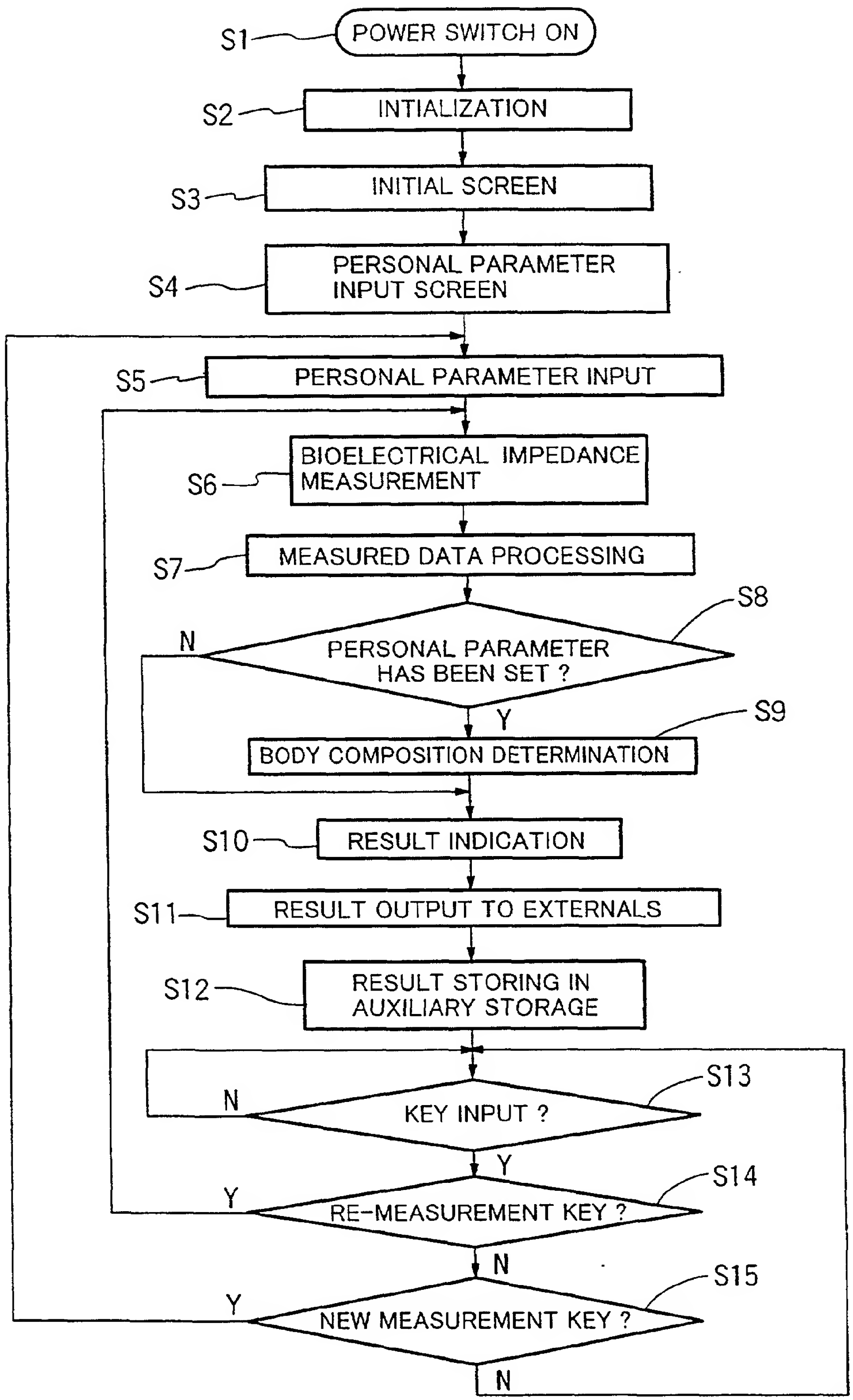

S1
POWER SWITCH ON
S2
INTIALIZATION
S3
INITIAL SCREEN
S4
PERSONAL PARAMETER INPUT SCREEN
S5
PERSONAL PARAMETER INPUT
S6
BIOELECTRICAL IMPEDANCE MEASUREMENT
S7
MEASURED DATA PROCESSING
S8
PERSONAL PARAMETER HAS BEEN SET ?
N
Y
S9
BODY COMPOSITION DETERMINATION
S10
RESULT INDICATION
S11
RESULT OUTPUT TO EXTERNALS
S12
RESULT STORING IN AUXILIARY STORAGE
S13
KEY INPUT ?
N
Y
S14
RE-MEASUREMENT KEY ?
Y
N
S15
NEW MEASUREMENT KEY ?
Y
N

FIG. 6

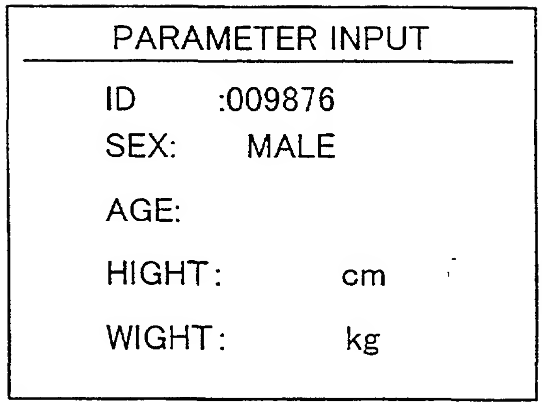

PARAMETER INPUT
ID :009876
SEX: MALE
AGE:
HIGHT: cm
WIGHT: kg

FIG. 7

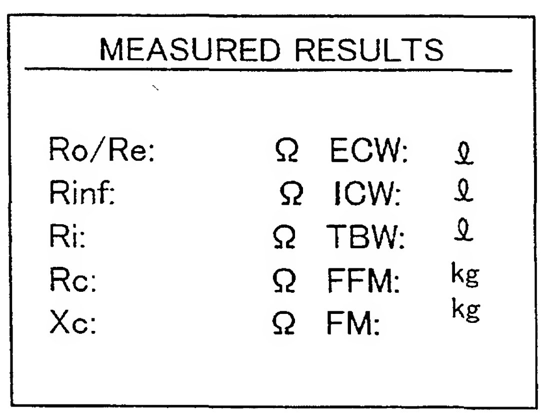

MEASURED RESULTS
Ro/Re: Ω ECW: ℓ
Rinf: Ω ICW: ℓ
Ri: Ω TBW: ℓ
Rc: Ω FFM: kg
Xc: Ω FM: kg

FIG. 8

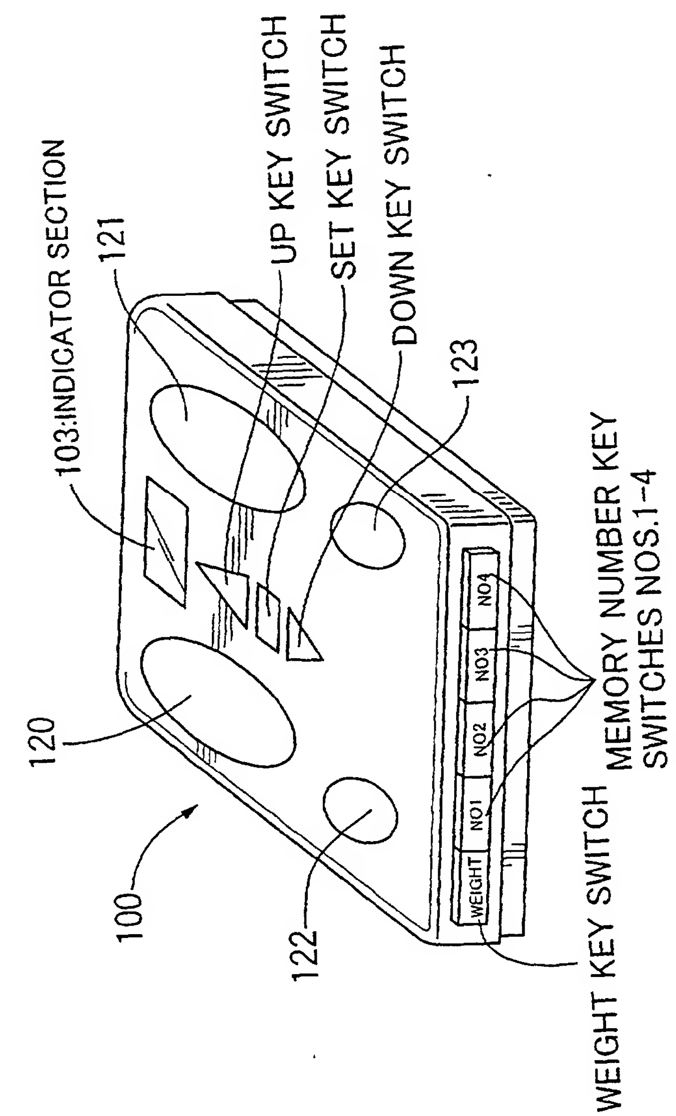

103:INDICATOR SECTION
121
UP KEY SWITCH
SET KEY SWITCH
DOWN KEY SWITCH
123
120
100
122
WEIGHT
NO1
NO2
NO3
NO4
MEMORY NUMBER KEY
SWITCHES NOS.1-4
WEIGHT KEY SWITCH

FIG. 9

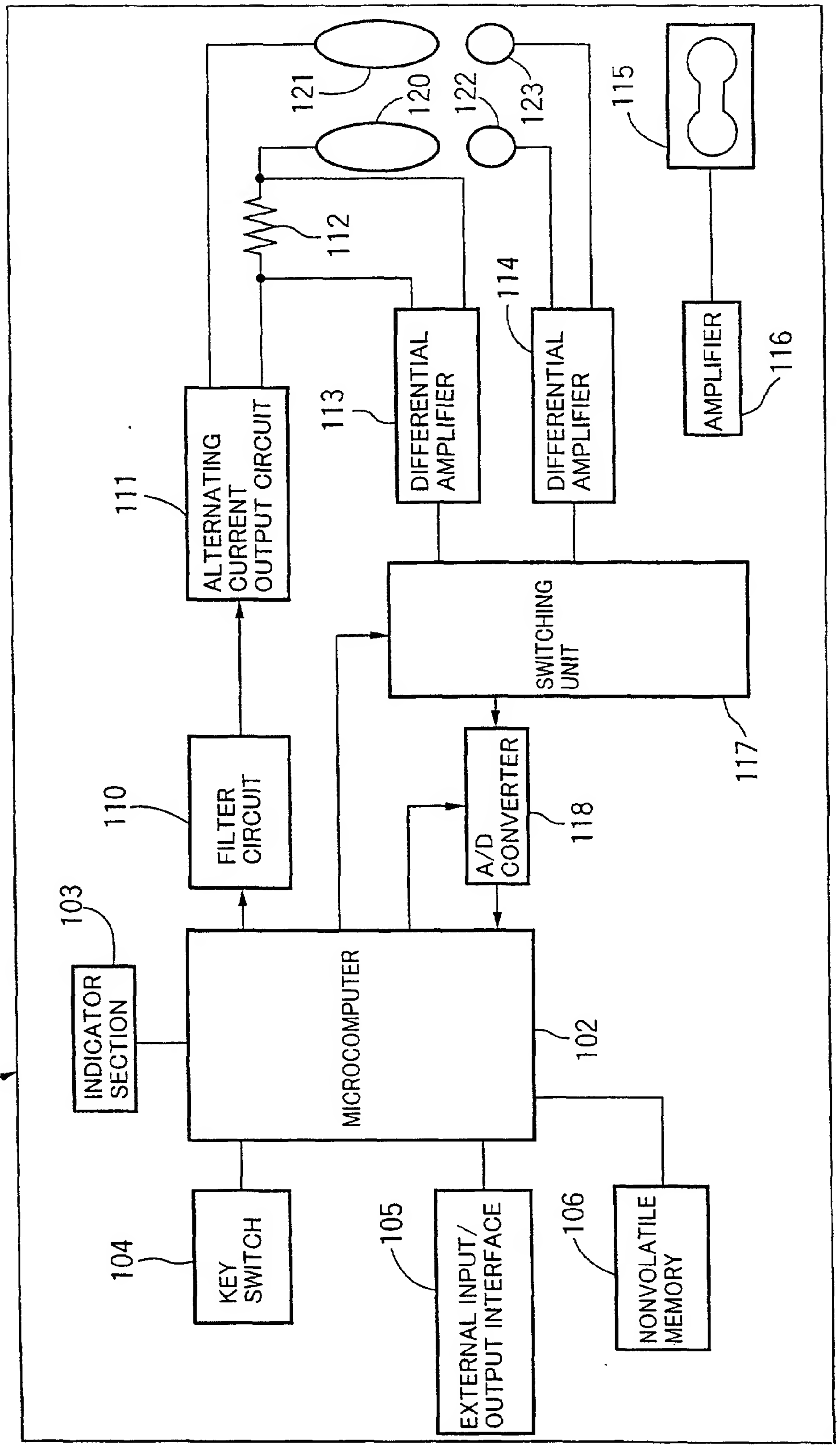
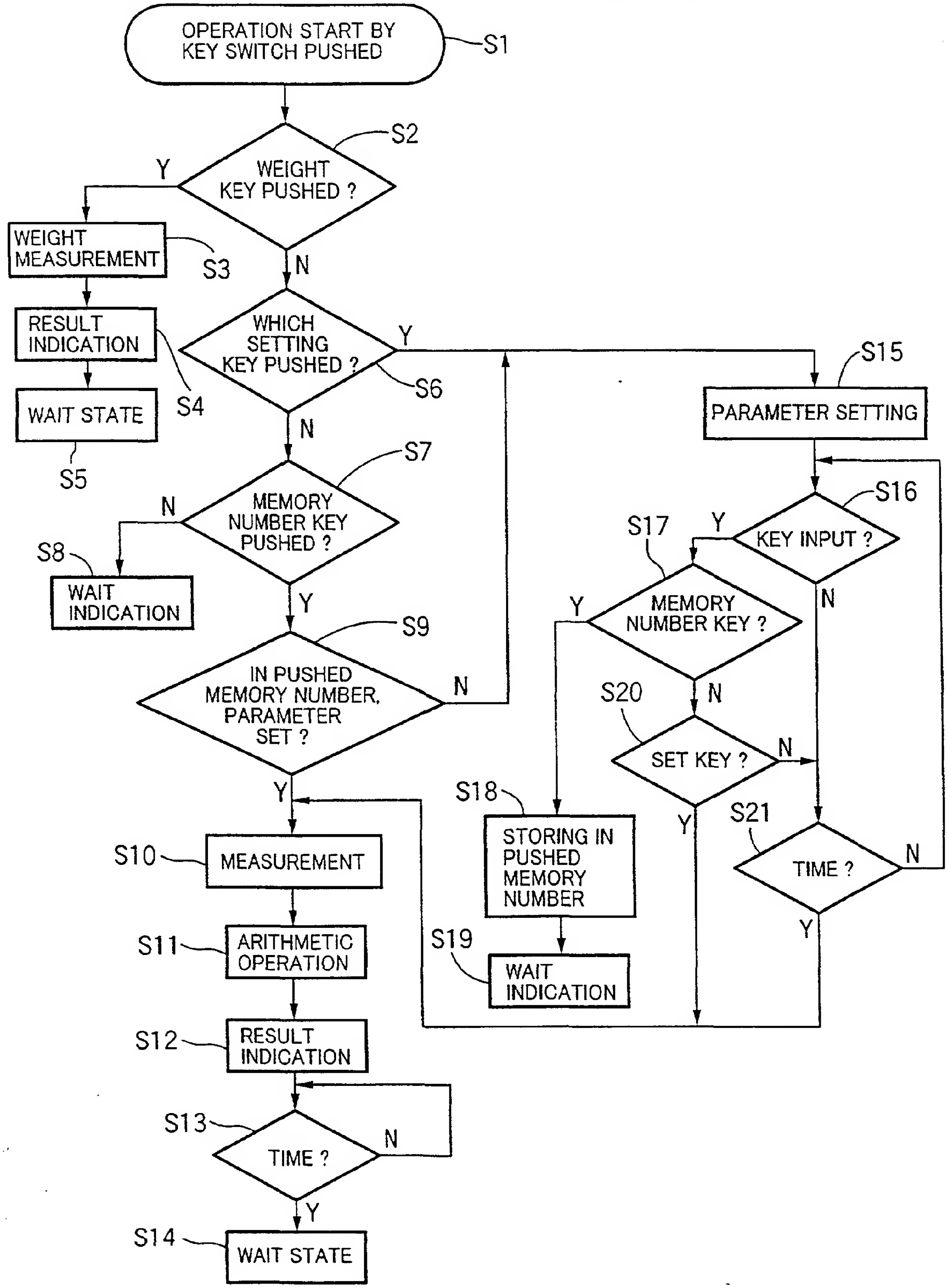

100
INDICATOR SECTION
103
MICROCOMPUTER
102
KEY SWITCH
104
EXTERNAL INPUT/ OUTPUT INTERFACE
105
NONVOLATILE MEMORY
106
FILTER CIRCUIT
110
ALTERNATING CURRENT OUTPUT CIRCUIT
111
112
DIFFERENTIAL AMPLIFIER
113
DIFFERENTIAL AMPLIFIER
114
SWITCHING UNIT
117
A/D CONVERTER
118
AMPLIFIER
116
115
120
121
122
123

FIG. 10


OPERATION START BY KEY SWITCH PUSHED
S1
WEIGHT KEY PUSHED ?
S2
Y
N
WEIGHT MEASUREMENT
S3
RESULT INDICATION
S4
WAIT STATE
S5
WHICH SETTING KEY PUSHED ?
S6
MEMORY NUMBER KEY PUSHED ?
S7
WAIT INDICATION
S8
IN PUSHED MEMORY NUMBER, PARAMETER SET ?
S9
MEASUREMENT
S10
ARITHMETIC OPERATION
S11
RESULT INDICATION
S12
TIME ?
S13
WAIT STATE
S14
PARAMETER SETTING
S15
KEY INPUT ?
S16
MEMORY NUMBER KEY ?
S17
STORING IN PUSHED MEMORY NUMBER
S18
WAIT INDICATION
S19
SET KEY ?
S20
TIME ?
S21